



# Search for Dark Matter with Liquid Argon and Pulse Shape Discrimination

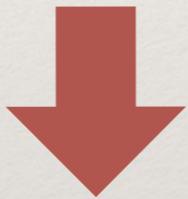
Results from DEAP-1 and Status of DEAP-3600

*Pierre Gorel for the DEAP collaboration*

*University of Alberta*

Dark matter  
Experiment using liquid  
Argon and  
Pulse shape discrimination

Single phase WIMP detector  
(Scintillation signal & Pulse Shape Discrimination)

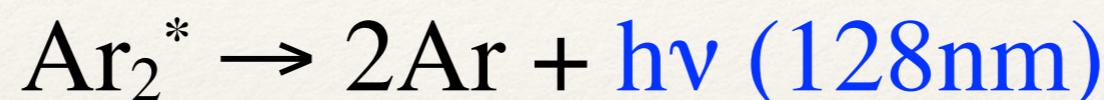


3 ton-year background-free data  
(in Region of Interest)

**Expected Sensitivity:  $\sigma_p = 10^{-46} \text{ cm}^2$  @  $M_\chi = 100 \text{ GeV}$**

# Argon scintillation (PSD)

Ionizing particle on Ar -> Dimer production



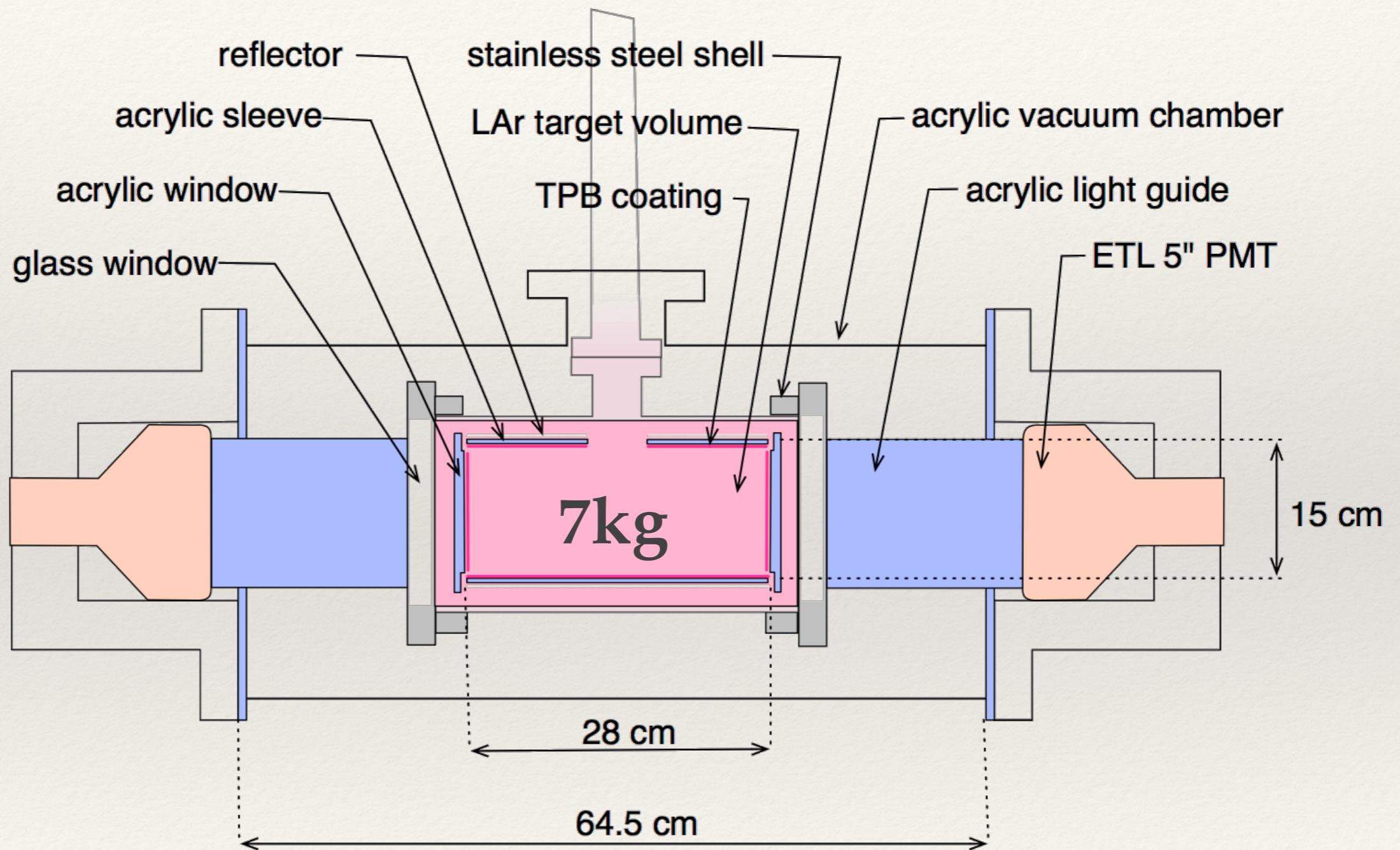
Two states: Singlet and Triplet

- ❖ Different time constant
- ❖ Populated depending on Linear Energy Transfer

Ionizing particle	Singlet (~7ns)	Triplet (~1.6μs)
Electron	33%	67%
Nucleus	75%	25%

→ WIMP Signal

# The prototype: DEAP-1



5 versions (2007-2011): Background & PSD

# DEAP-1: what did we learn ?

- ❖ PSD strongly depending on Light Collection

P-A Amaudruz *et al.* (submitted to Astroparticle Physics)

- ❖ Good understanding of:

- Background in ROI: PSD leakage & Surface  $\alpha$
- Radon control:  $^{222}\text{Rn} \sim 16 \mu\text{Bq}/\text{kg}$   
 $^{220}\text{Rn} \sim 2 \mu\text{Bq}/\text{kg}$

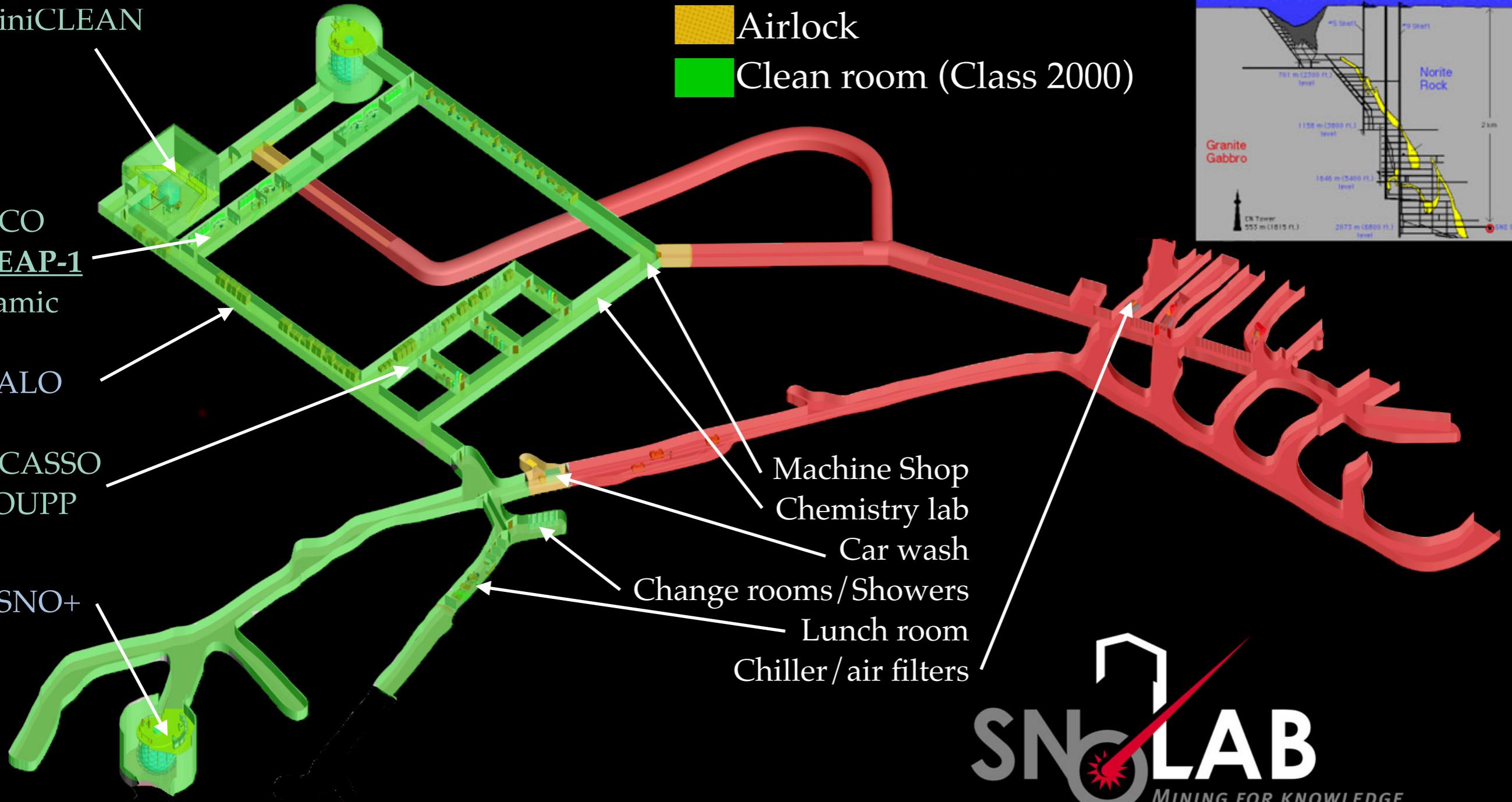
arXiv:1211.0909v2

(submitted to Astroparticle Physics)

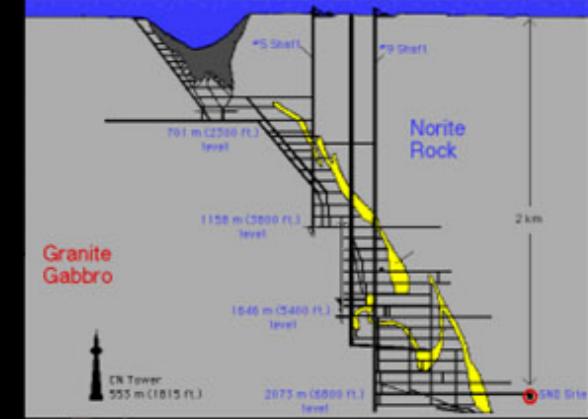
3 ton-years background-free possible  
from extrapolation on measured PSD

## DEAP-3600

MiniCLEAN



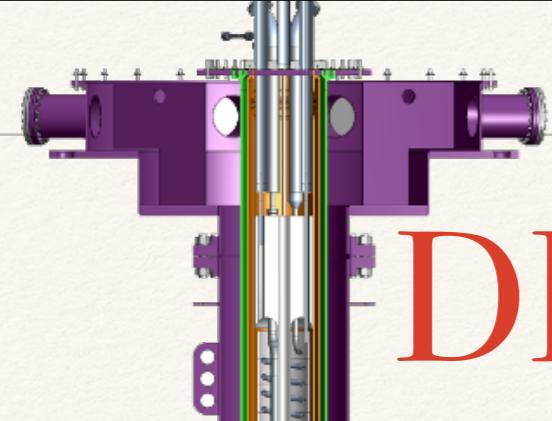
Vale  
Creighton Mine #9 Shaft



2073 m Underground (6010 mwe) => 0.23 muon/m<sup>2</sup>/day

A day at SNOLAB: <http://www.youtube.com/watch?v=sZPLcv-ASwc>

SNOLAB Virtual Tour: <https://www.snolab.ca/facility/vr-tour>



# DEAP-3600:

Maximum light collection  
Background mitigation

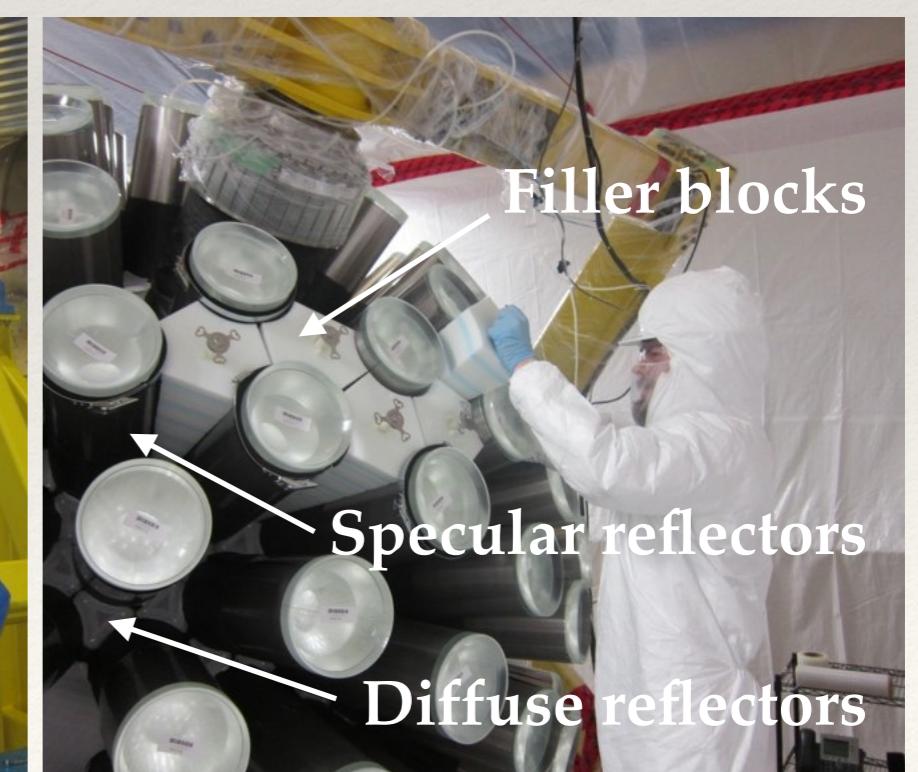
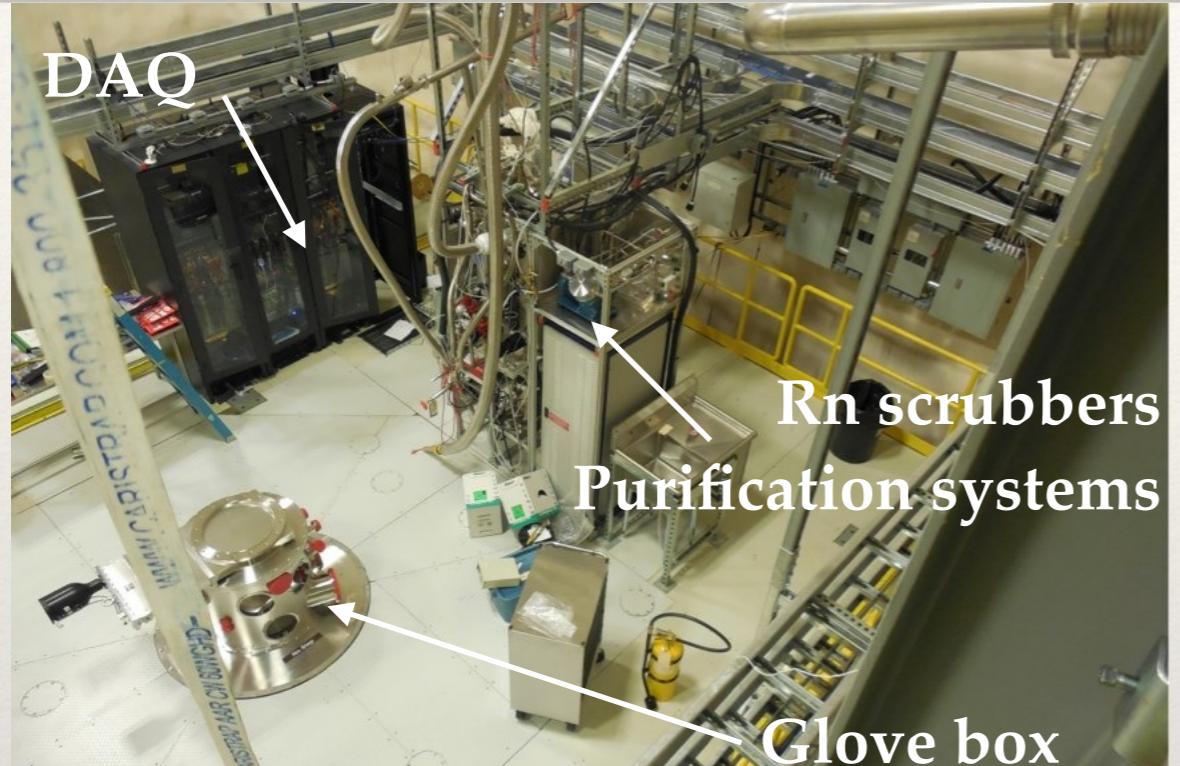
- 3600 kg of Liquid Argon
- 1000 kg Fiducial mass

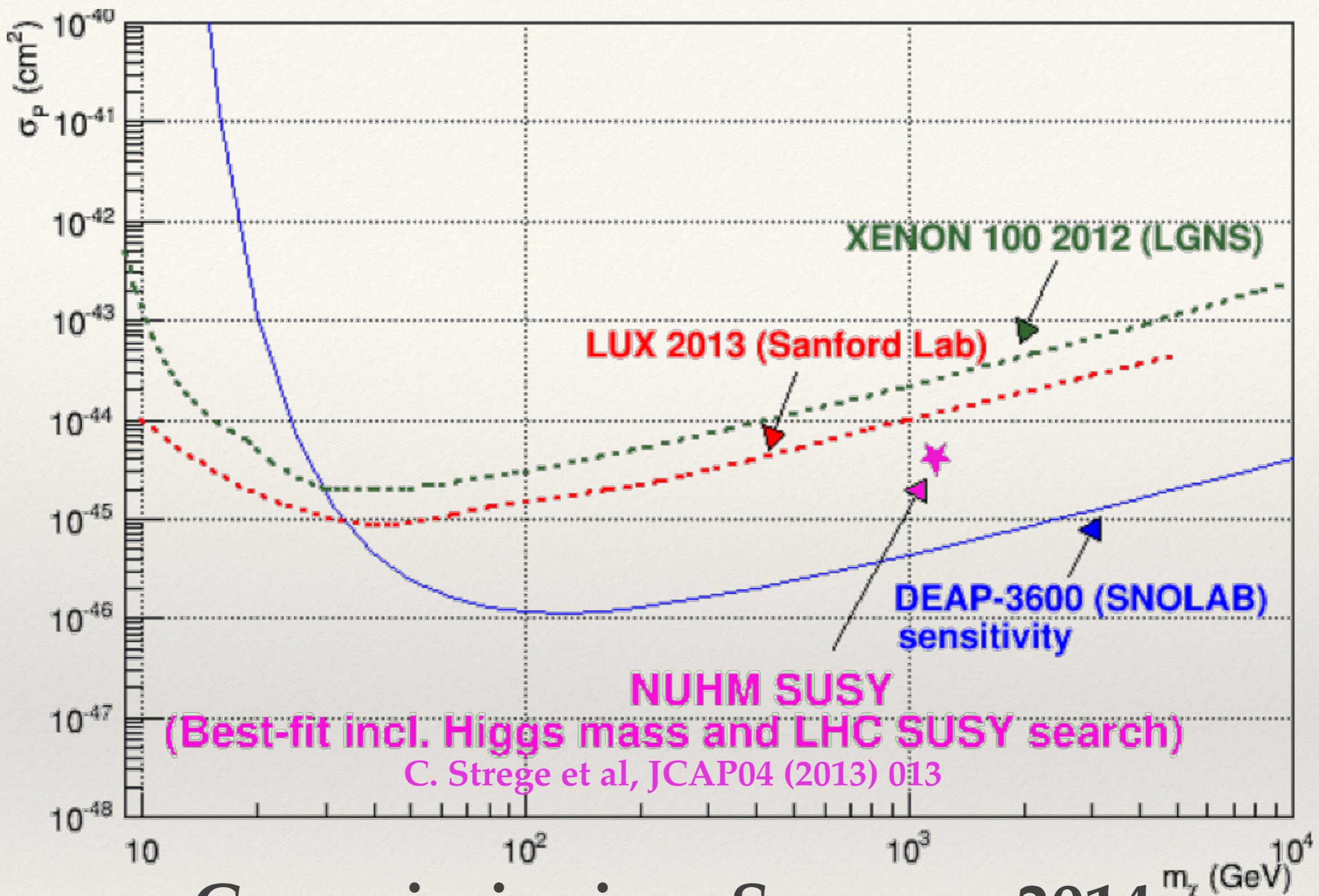
- 255 8" Photomultipliers
  - Hamamatsu R5912, HQE
  - 75% Coverage

- Spherical acrylic vessel
  - Cast from distilled monomer
  - Inner 1mm layer removed after construction
- Neutron shielding against  $(\alpha, n)$  in PMT glass
- Light guides (acrylic)
- Filler blocks (polyethylene+styrofoam)

- Ø7m x 7m ultra-pure water tank
  - Shield against rock radioactivity
  - Muon Veto (48 PMTs)

# Construction status





Commissioning: Summer 2014

Physics data: Fall 2014

Leading sensitivity: 2 months of data



UNIVERSITY OF  
ALBERTA



Carleton  
UNIVERSITY



Laurentian University  
Université Laurentienne



Queen's  
UNIVERSITY



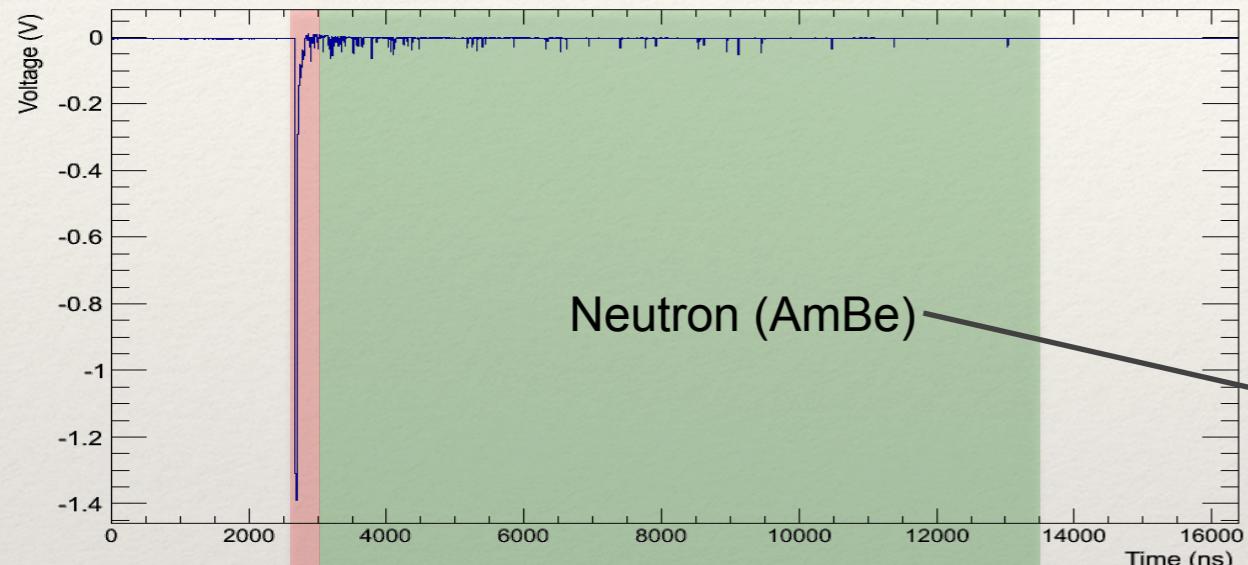
US University  
of Sussex



# Backup slides

# DEAP-1: PSD

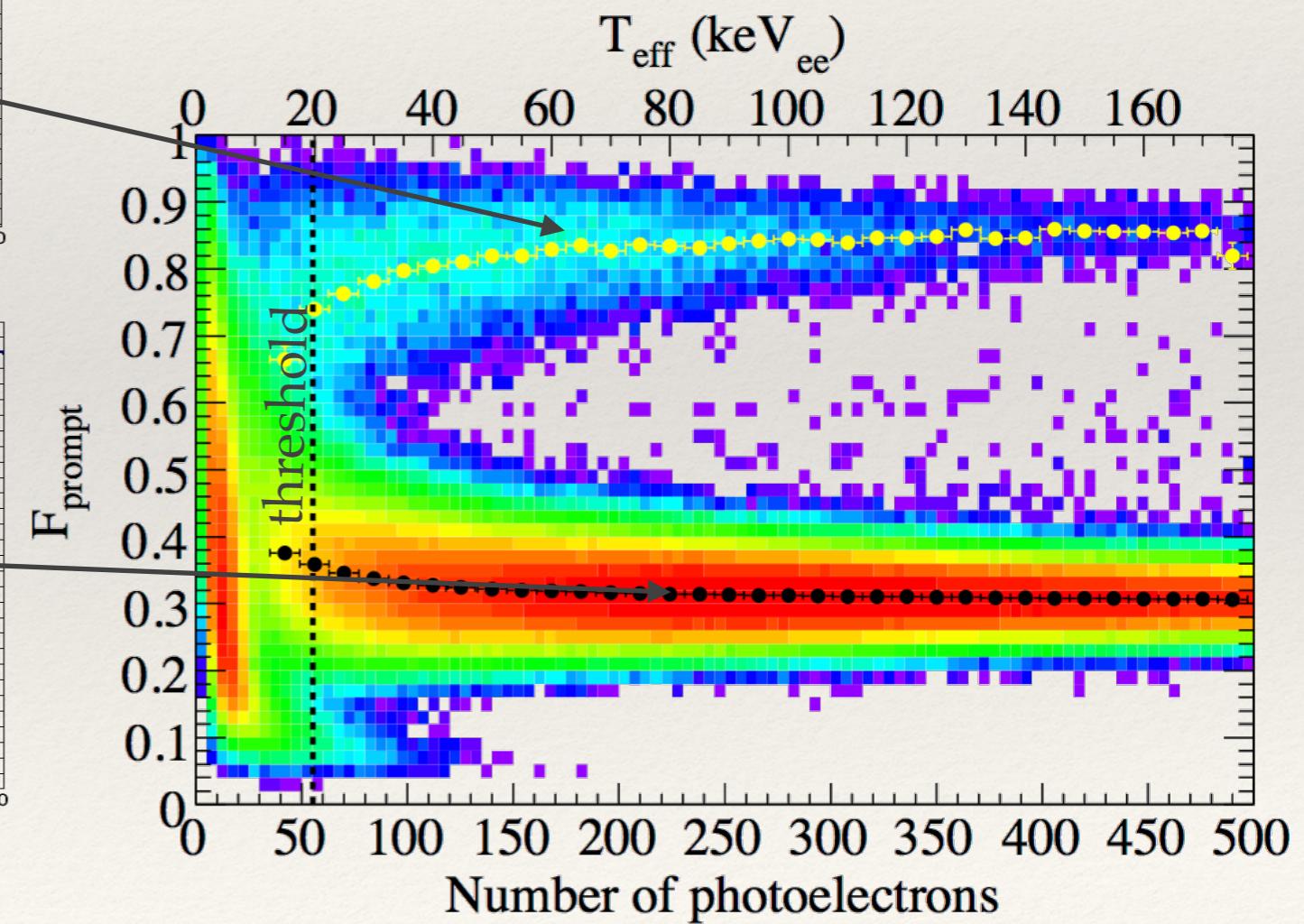
Electric signal from PMT:



Prompt : 0-150ns  
Late: 150ns-10μs

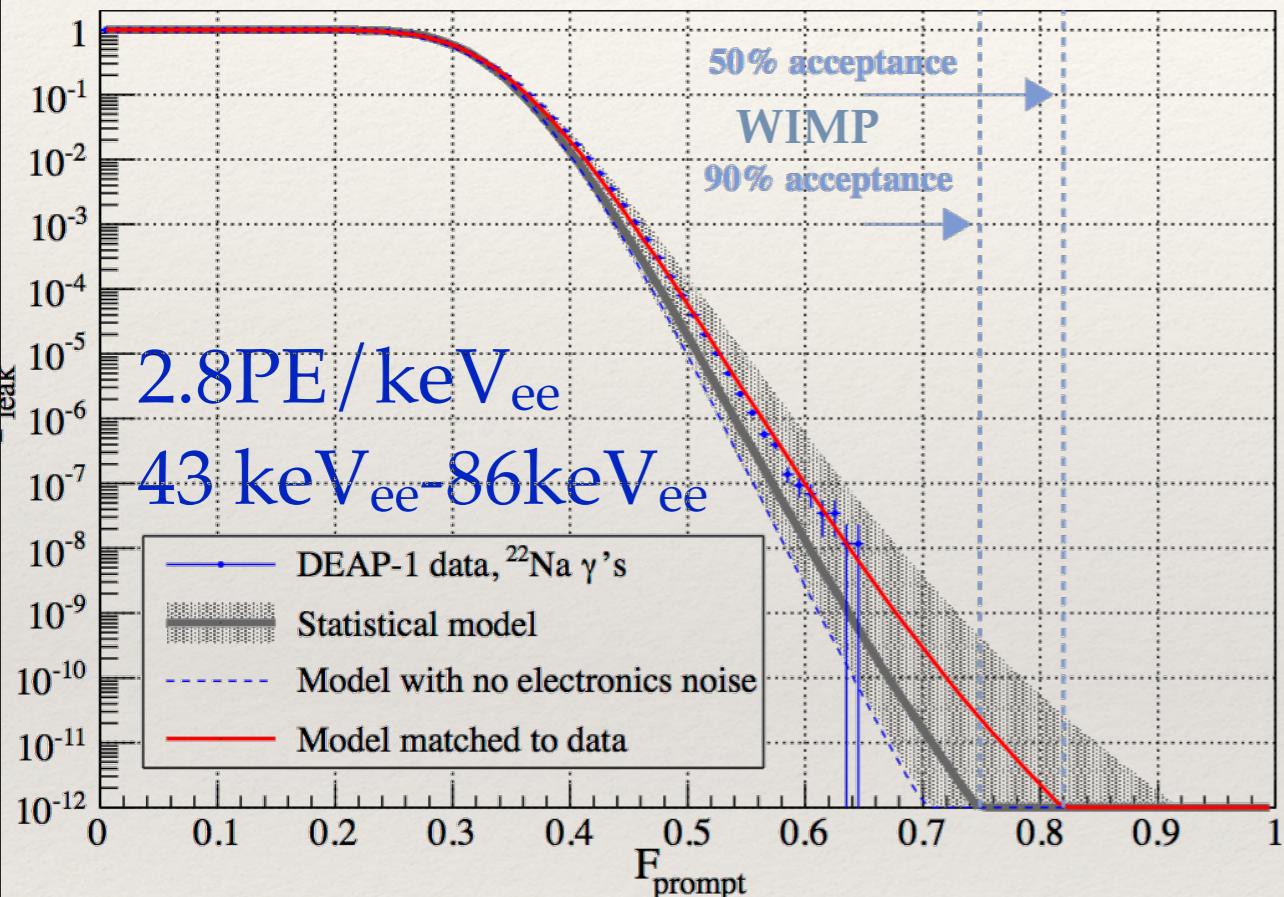
Photon-electron counting:

$$FPrompt = \frac{N_{prompt}}{N_{prompt} + N_{Late}}$$

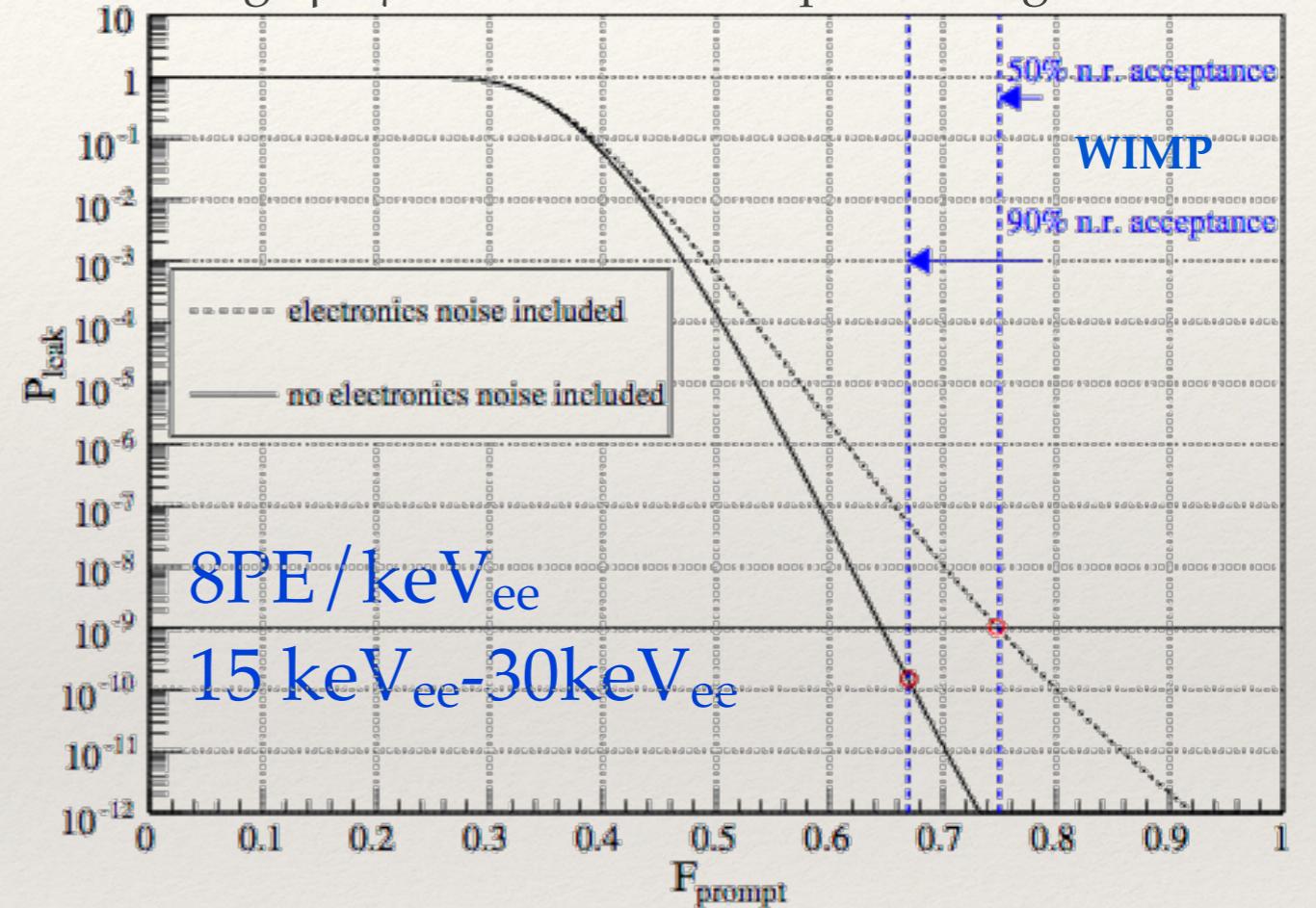


# DEAP-1: PSD performance

Leakage  $\beta/\gamma$  into ROI (DEAP-1, measured)



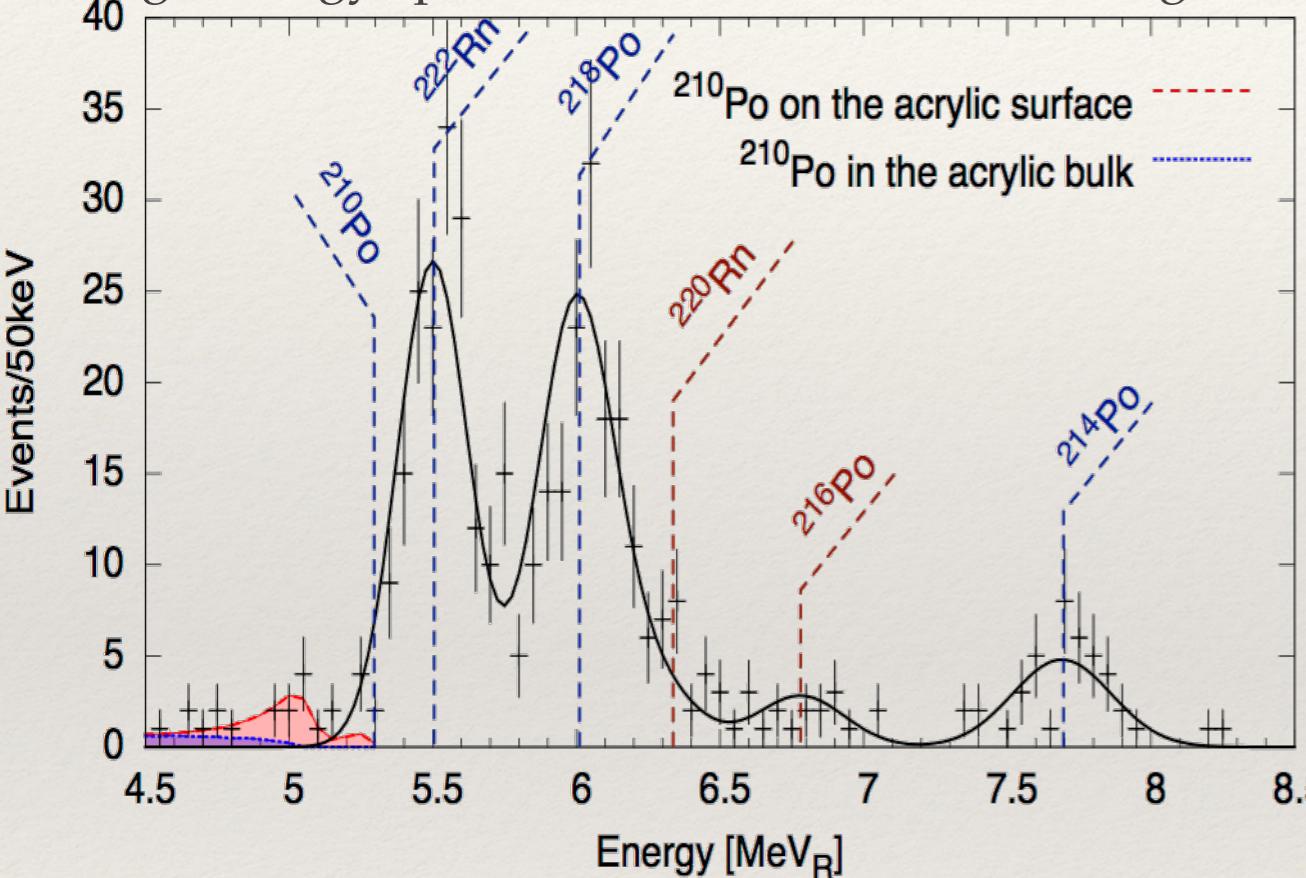
Leakage  $\beta/\gamma$  into ROI with improved Light Collection



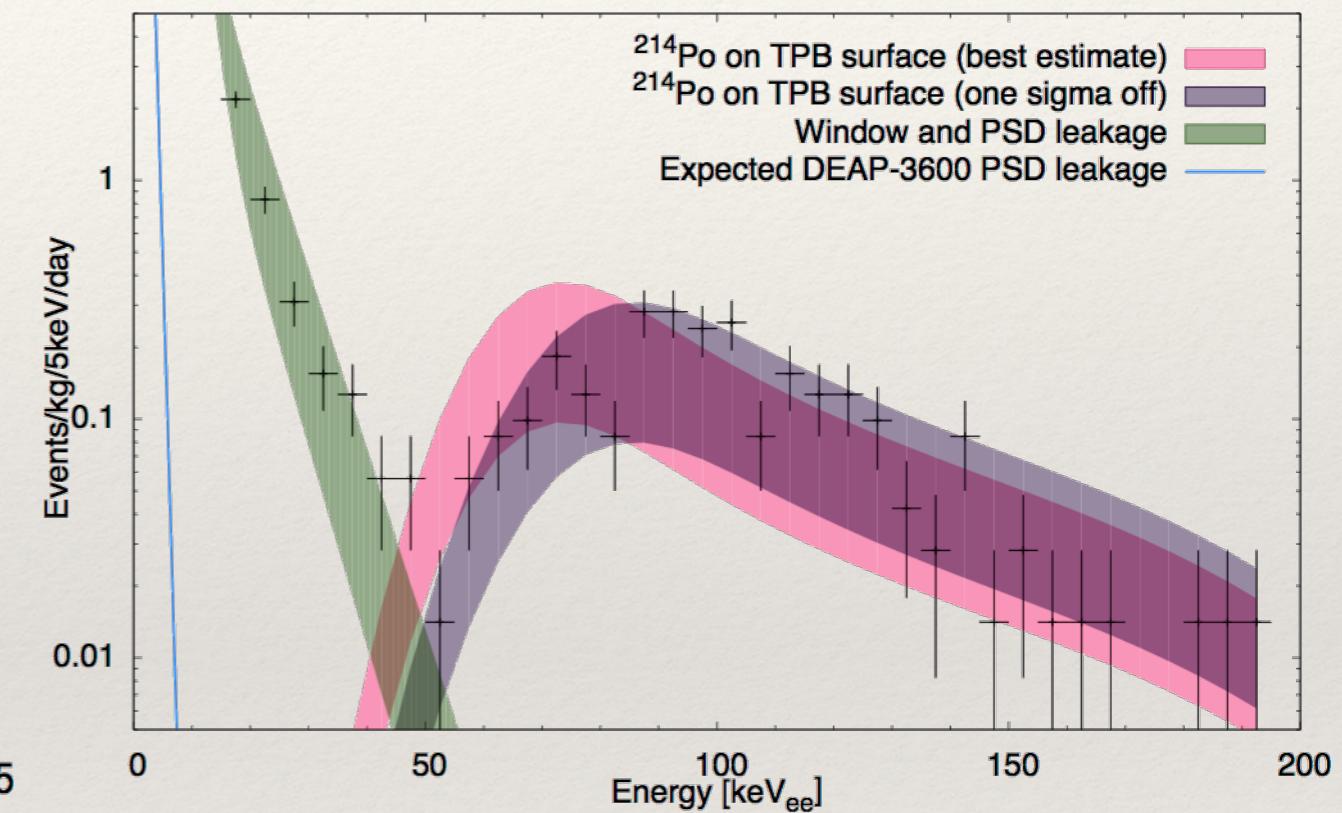
Increased light Collection  
=> Better PSD / Lower threshold

# DEAP-1: Background

High energy spectrum, fitted with Radon daughters

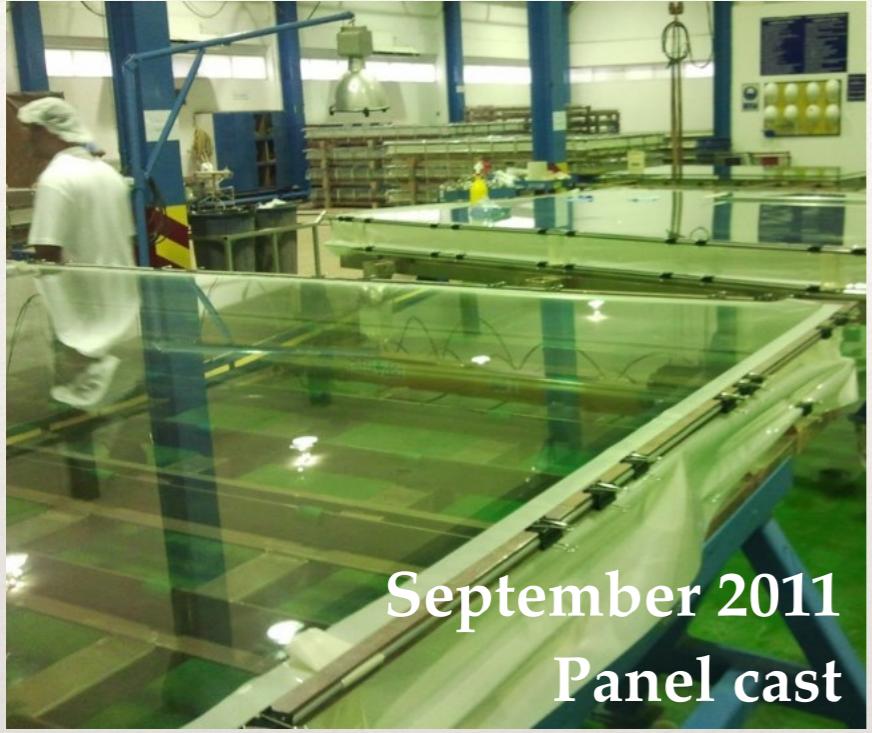


Low energy spectrum in ROI:



Low energy cut off + improved PSD  
=>NO  $\alpha$  background in WIMP window

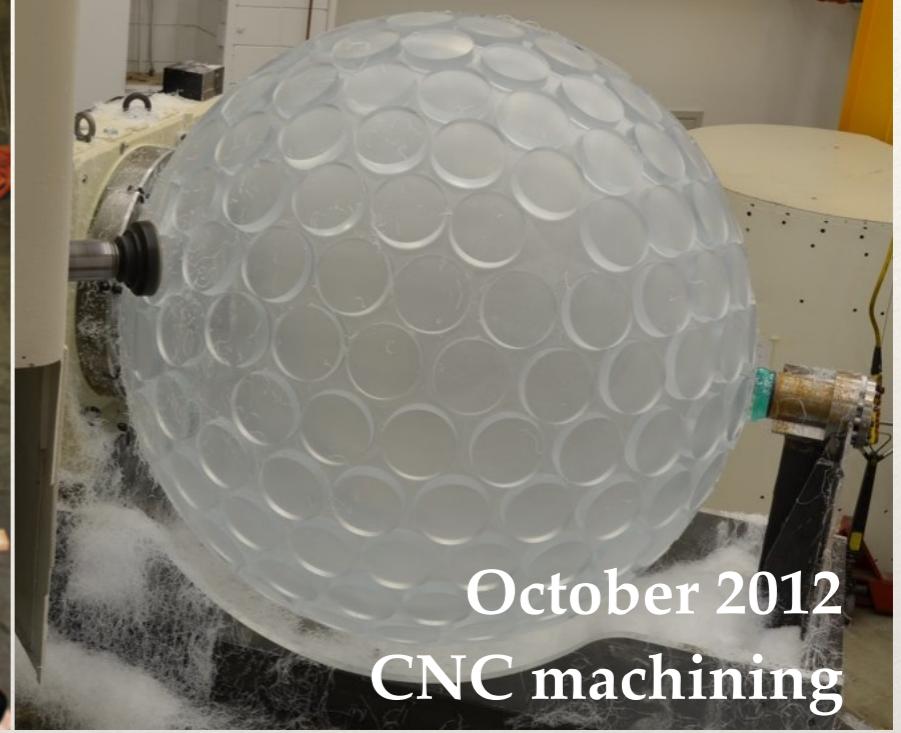
# AV construction



September 2011  
Panel cast



April 2012  
Panels bounding



October 2012  
CNC machining



January 2013  
Neck and shoulder  
bonding



July 2013  
Light guides bonding



February 2014  
Cleaning

# Resurfacer

- ❖ Mechanical removal: 1mm acrylic
- ❖ Flush with Ultra-Pure Water
- ❖ Rn-scrubbed N<sub>2</sub> cover gas

=> Contamination level to bulk purity  
( $<10^{-19}$ g/g of <sup>210</sup>Pb)

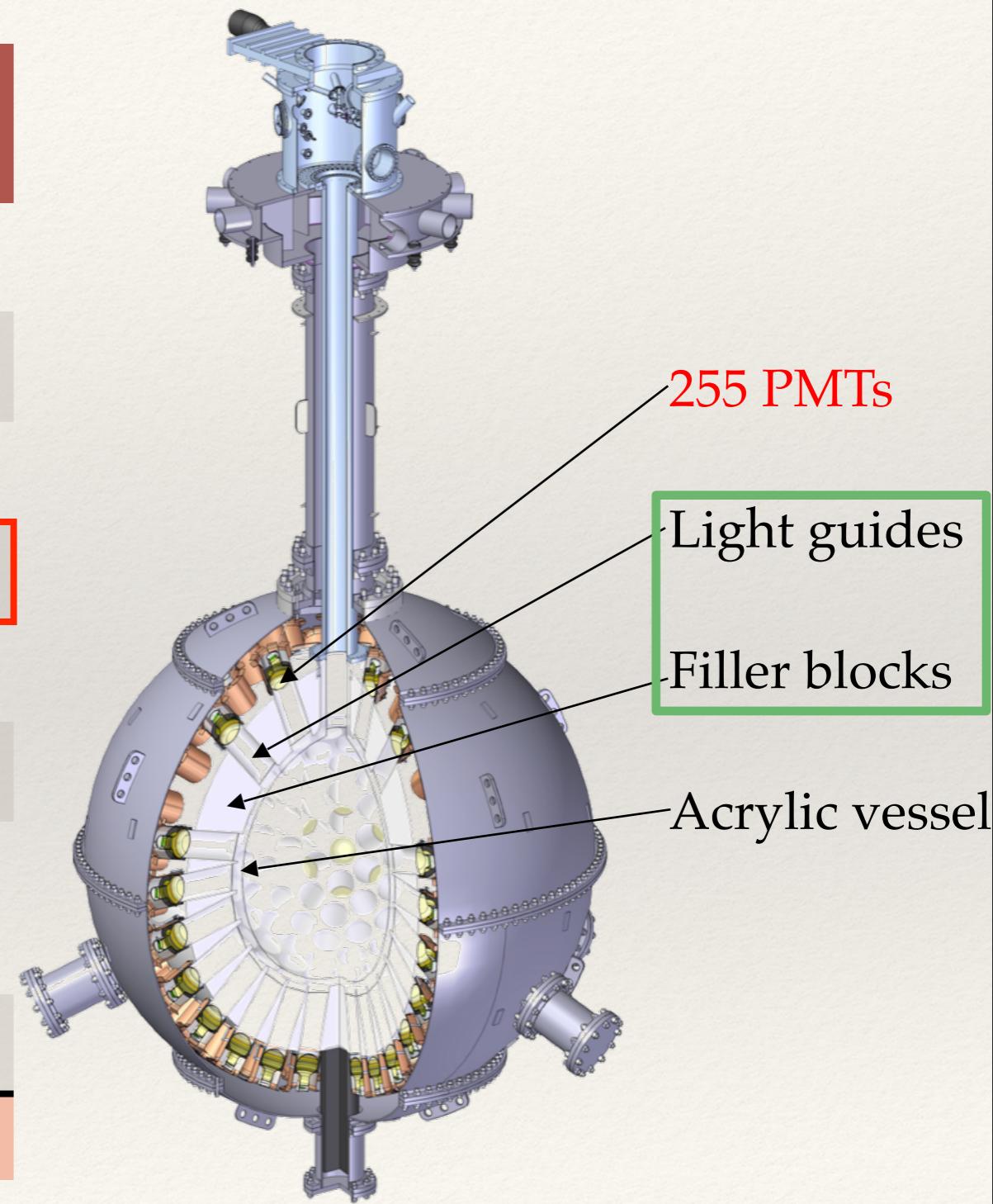
# DEAP-3600: Background budget

Background	Rate/Count	Mitigation
Neutron in 1t LAr	< 2 pBq/kg < 0.06 count/year	Shielding (6000 mwe, active water shield Light guides and filler block) Material selection
$\beta/\gamma$ in 1t LAr	< 2 pBq/kg < 0.06 count/year	Pulse Shape Discrimination Material selection
Radon in 1t LAr	< 1.4 nBq/kg < 44 count/year	Material selection SAES getter Cold charcoal radon trap
Surface $\alpha$ in 1t LAr	< 0.2 mBq/m < 0.6 count/year	Material selection Resurfacing Fiducialization

**Total: <0.6 events in ROI in 3 years of data taking**

# Neutron background in DEAP-3600

(In 3 years)	# of neutrons (produced)	Events in ROI
Acrylic vessel	<44 (Ge $\gamma$ -assay)	<0.096
Light guides	<127 (Ge $\gamma$ -assay)	<0.015
Filler blocks	<173 (Ge $\gamma$ -assay)	<0.034
PMTs	$2.6 \times 10^3$	0.140
PMT mounts	7565	0.010
Rn emanation	<44	<0.081
Rn deposition (3 months)	38	0.010
Other sources		0.04
<b>Total</b>	<b>&lt;2.7x10<sup>3</sup></b>	<b>&lt;0.35</b>



# Calibration program

Calibration Tools	Optical Response	Energy Reconstruction	Radius Reconstruction	Detector response and stability vs time
LED, lasers, in-situ single PE tails	✓	✓		✓
Gamma sources (tagged $^{137}$		✓	✓	✓
Neutron sources (DD generator, AmBe)		✓	✓	✓
In-situ radioactivity ( $^{39}$ gammas)	✓	✓	✓	✓